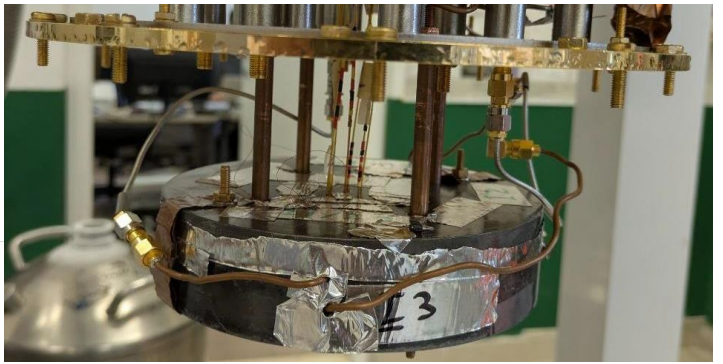
SAPIENZA
UNIVERSITÀ DI ROMA

Background with mild shield: N-dimensional filter analysis

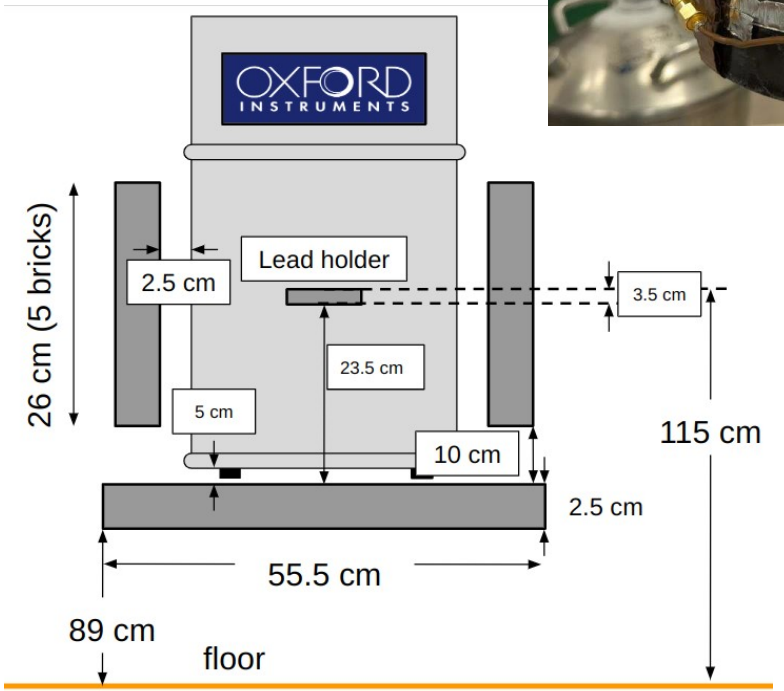
BULLKID Digest
23/09/2025
Matteo Cappelli

Background with mild shield

Data with internal and external lead shield.
290 hours for 2 clusters with 15 KIDs.
19 Apr 22:00 – 5 May 8:00.
Presentation by D. Delicato at the last collaboration meeting.

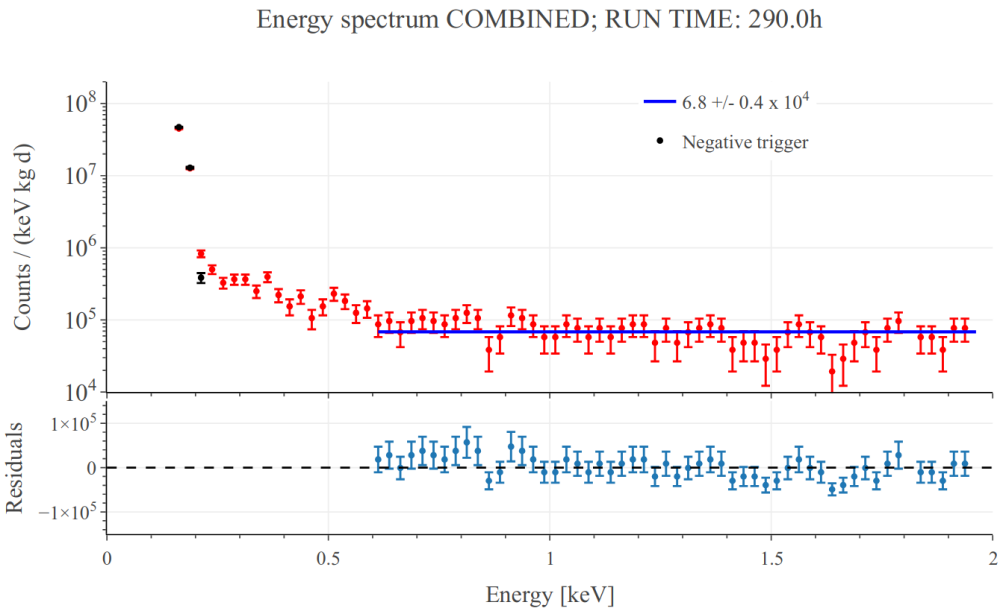


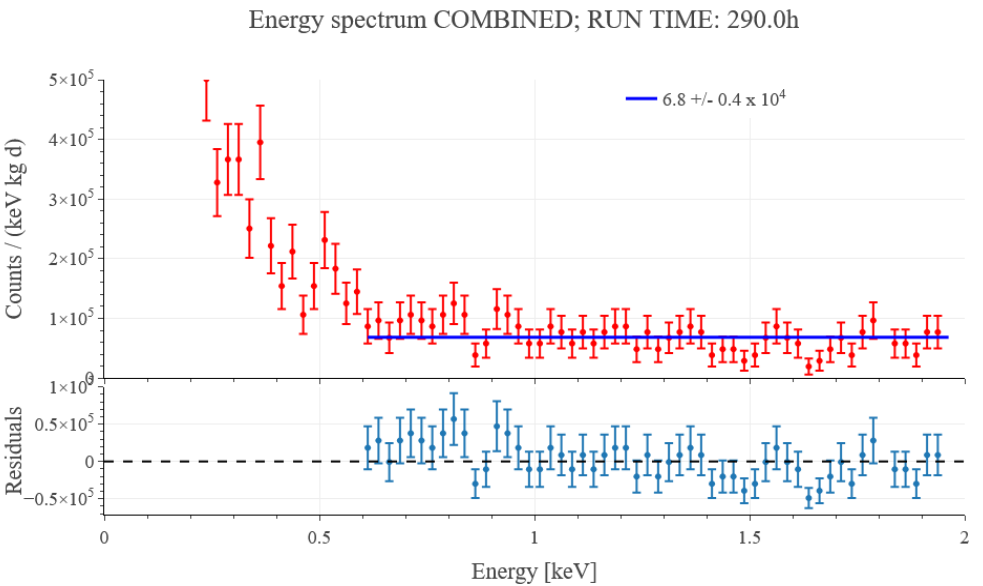
		1	2	3	4	5	
13	12	11	10	8	7	9	6
14	15		16	17	18		19
27	26	25	24	23	22	21	20
29	28	30	31	32	33	34	35
43	42	41	40	39	38	36	37
44	45	46	47	48	49	50	51
	57	56	55	54	53	52	



Low energy spectrum results

Flat component [600 eV – 2 keV] compatible with simulations.
Below 600 eV we see an increase of a factor ≈ 5 which is under investigation.





Usual cuts on shape parameters of the optimum filter and cluster/coincidence cuts.

Low energy analysis with N dimensional filter

Preliminary analysis of pixel 47 with the N dimensional optimum filter (OFND).

The filtered signal is:

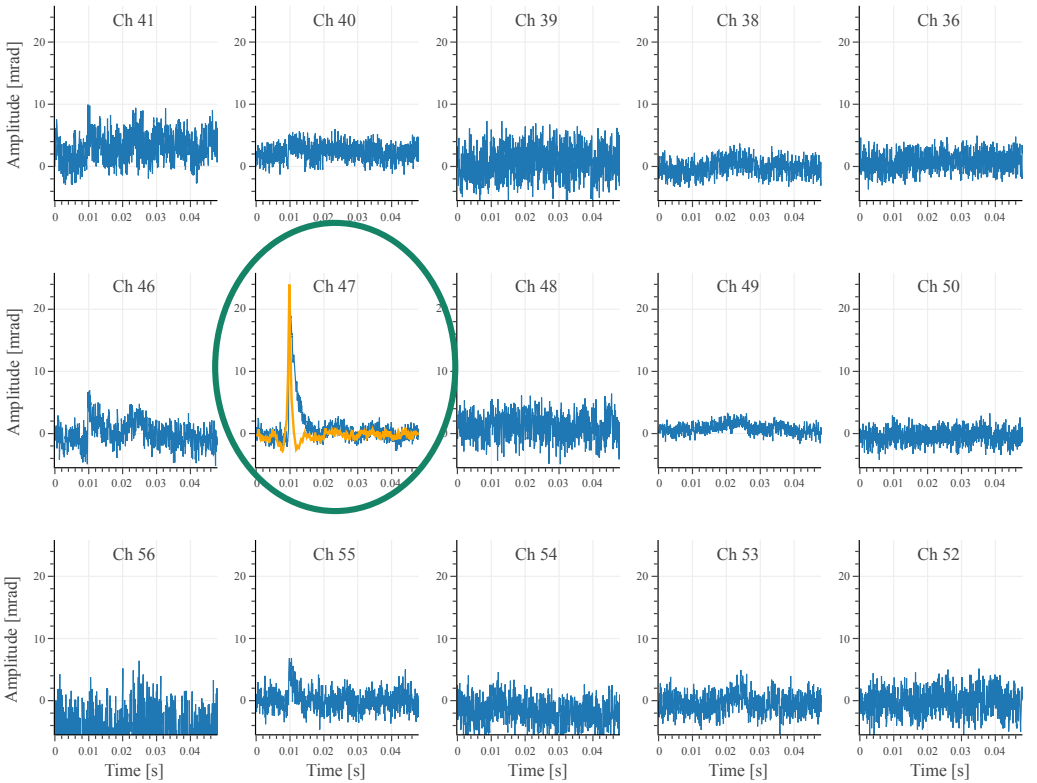
$$\tilde{v}_{\mathrm{filt}}(f) = \frac{1}{K} \sum_{a,b=1}^{N} \tilde{s}_a^*(f) \hat{\sigma}_{ab}^{-1} \tilde{v}_b(f)$$

templates — noise covariance — waveforms

Combines the signals on different detectors to improve the amplitude resolution.

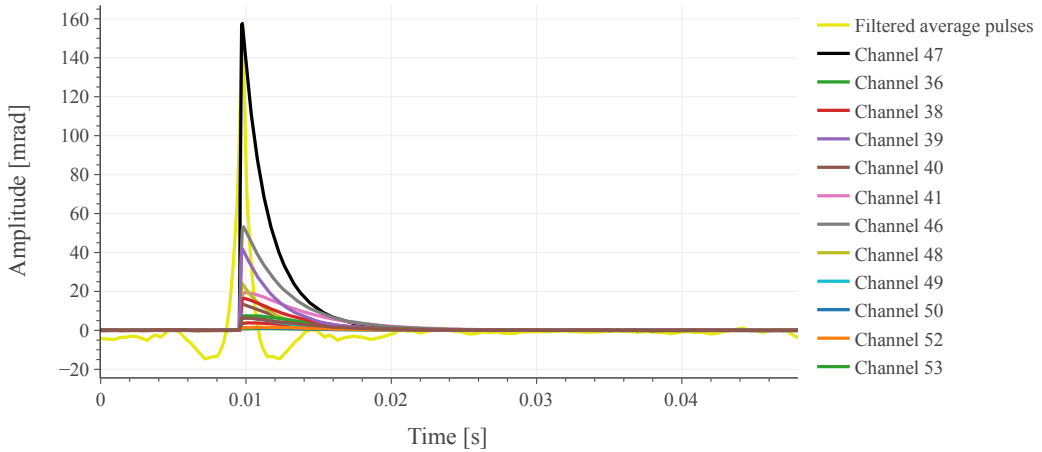
Talk at collaboration meeting in Pisa.

Goals:
- Reduce the impact of negative triggers near threshold
- Find new shape variables to cut on and investigate the background rise

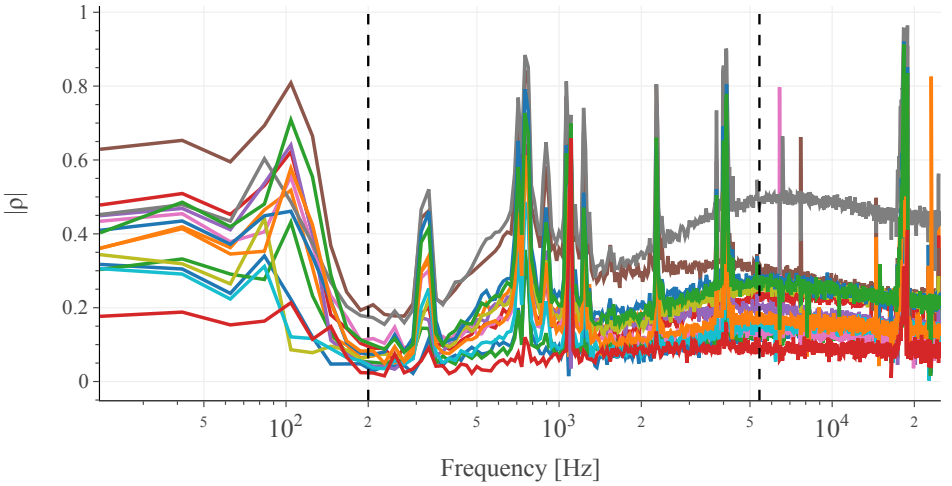


Constructing the filter

Array of average pulses, with pixel 47 as the main channel and the other templates built with events in coincidence.



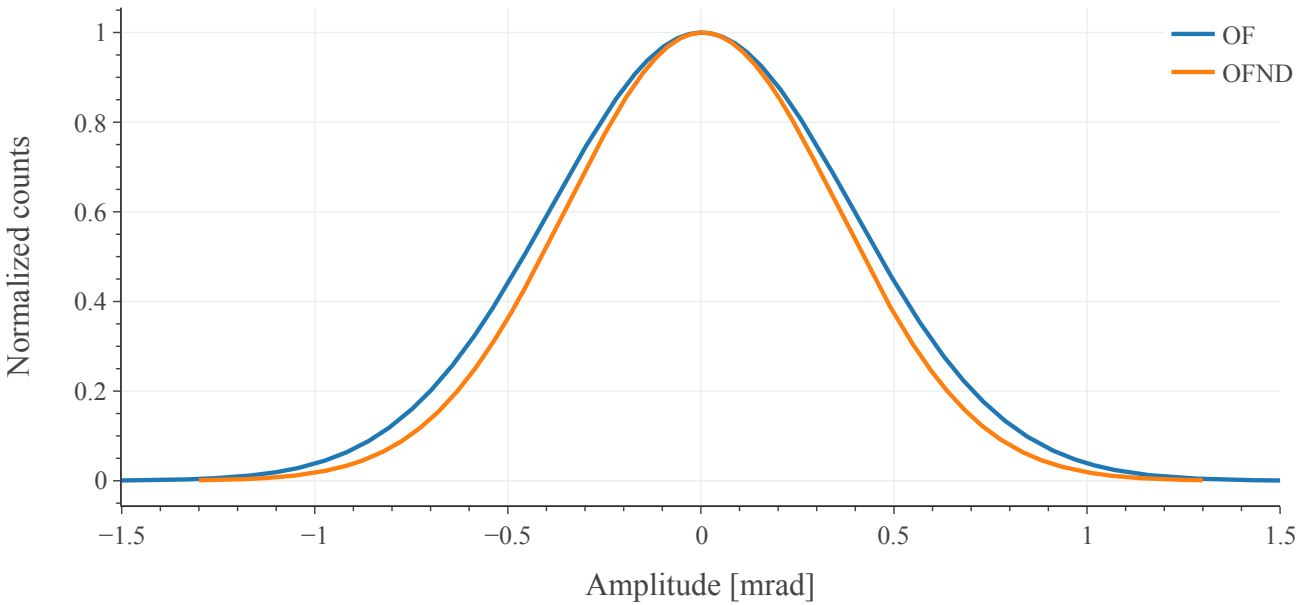
Noise correlation between main channel 47 and neighbors channels



- Expected baseline resolution with OF: 0.3980 mrad
- Expected baseline resolution with OFND: 0.3548 mrad
- Expected gain in resolution: ≈ 10 %

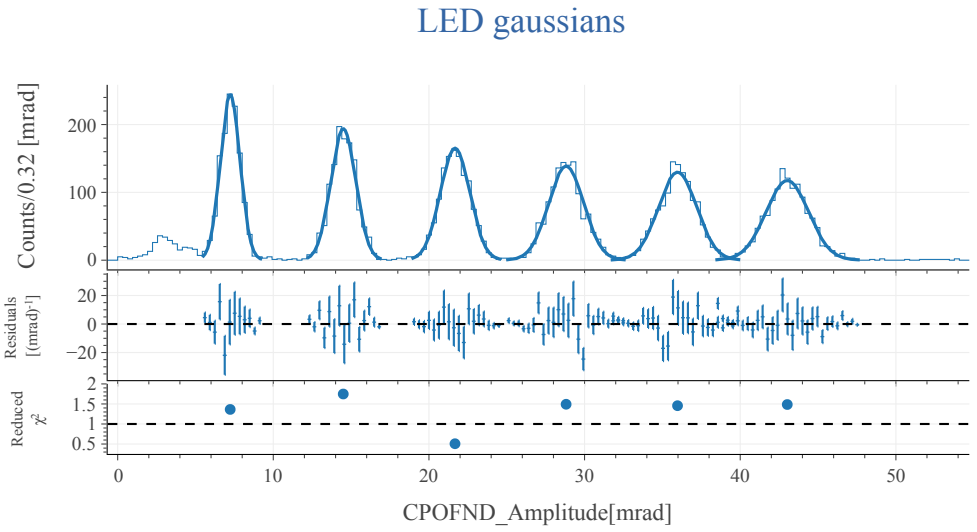
Baseline resolution in mrad

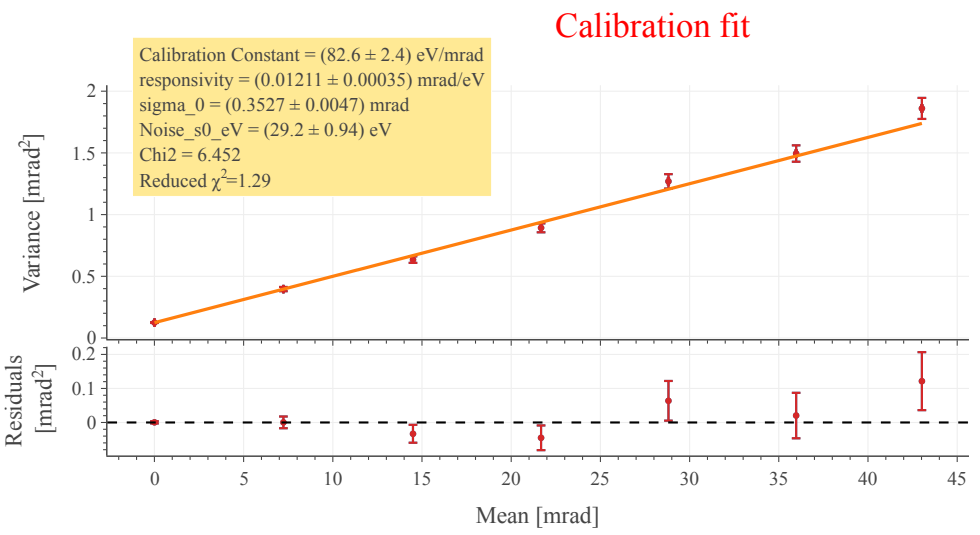
Indeed, a gain in the baseline resolution of 9.7 % with respect to the standard optimum filter was observed with the multidimensional filter.

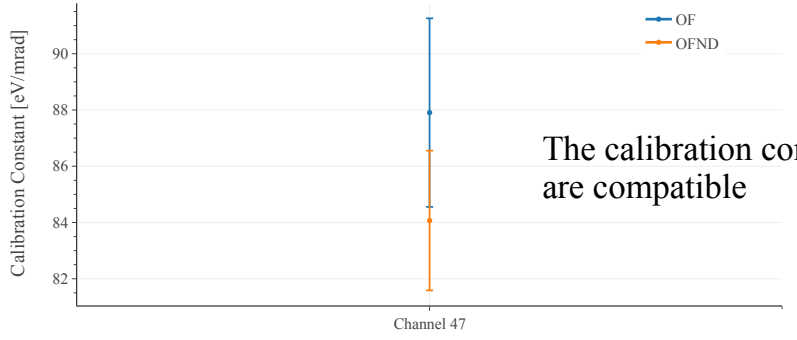


LED calibration

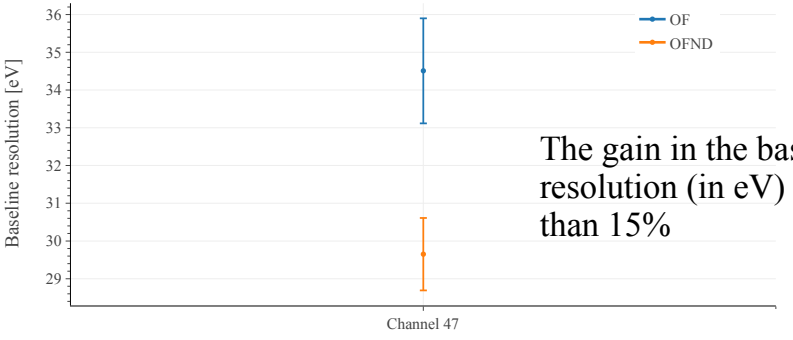
Compare the LED calibration with OF and OFND.







The calibration constants are compatible



The gain in the baseline resolution (in eV) is more than 15%

New shape variable

A new shape variable can be obtained with this formalism. First, evaluate an amplitude not considering the main channel.

$$\tilde{v}_{\text{filt}}(f) = \frac{1}{K} \sum_{a,b=1}^{N} \tilde{s}_a^*(f) \hat{\sigma}_{ab}^{-1} \tilde{v}_b(f)$$

Filtered signal **with the main channel**

↓

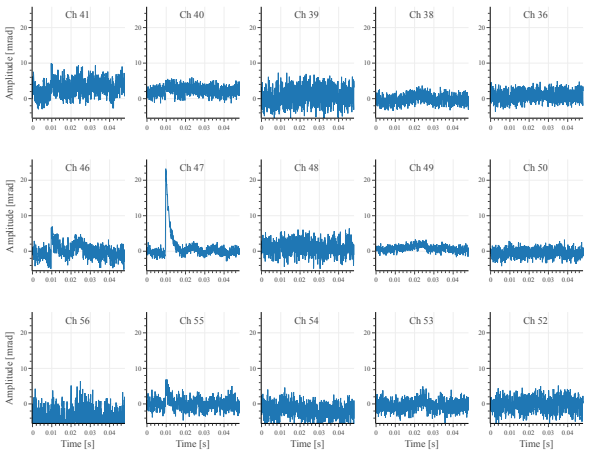
amplitude *A*

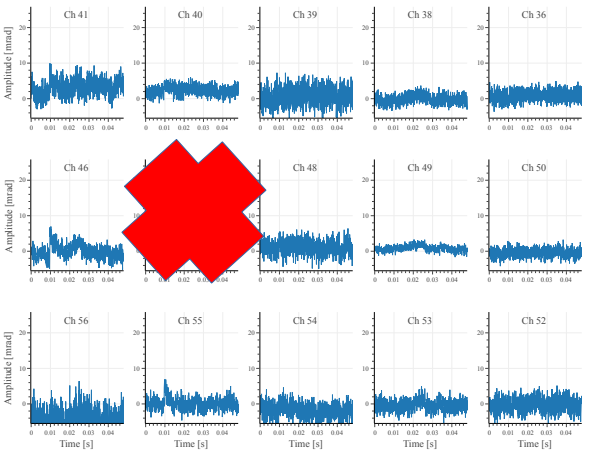
$$\tilde{v}'_{\text{filt}}(f) = \frac{1}{K'} \sum_{\substack{a,b=1 \\ a,b \neq \text{main}}}^{N} \tilde{s}_a^*(f) \hat{\sigma}_{ab}^{-1} \tilde{v}_b(f)$$

Filtered signal **without the main channel**

↓

amplitude *A'*





New shape variable

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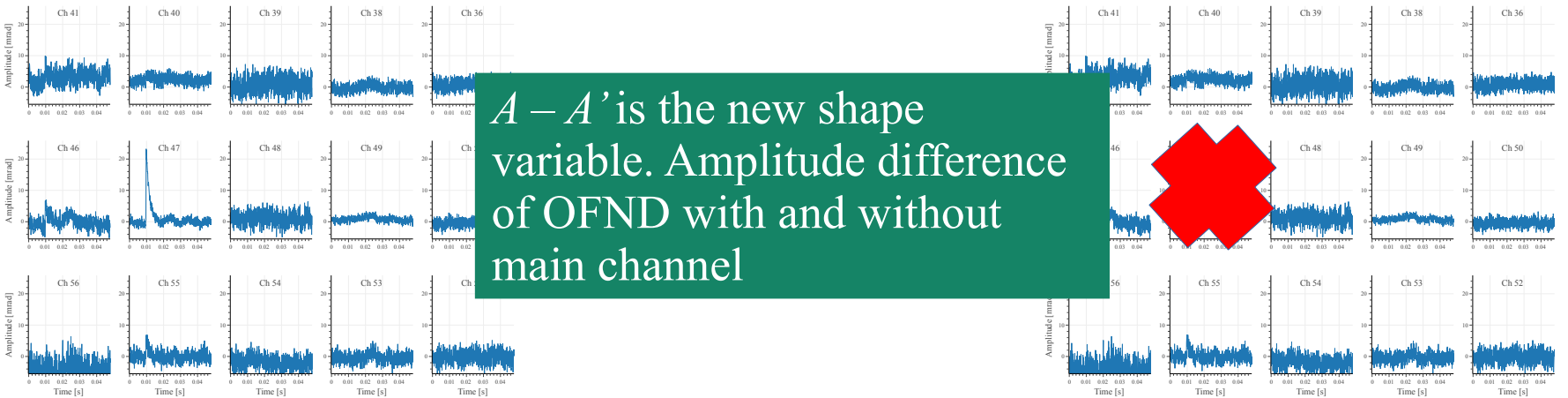
Filtered signal **without the main channel**

↓

amplitude *A'*



A – A' is the new shape variable. Amplitude difference of OFND with and without main channel

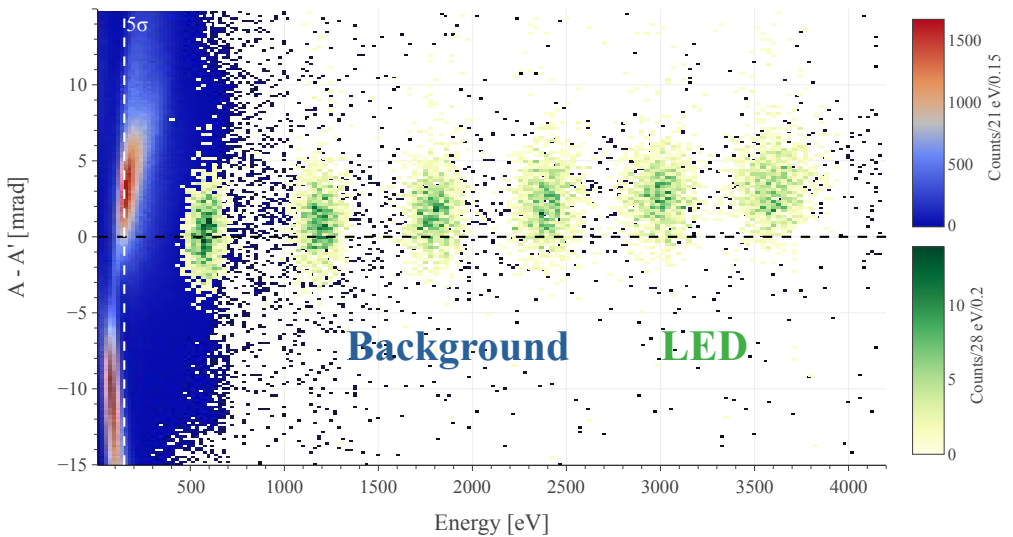
New shape variable linearized

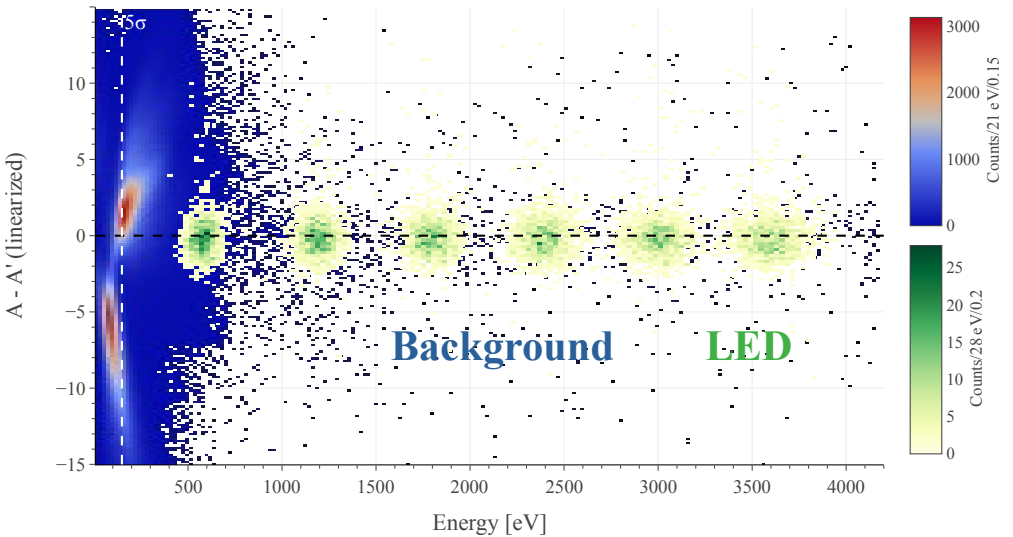
Linearize and normalize the variable in a way that is linear and independent of the energy.

Linearization procedure (subtract the mean
and divide by the standard deviation)

Energy dependence

Normal distributions centered around zero



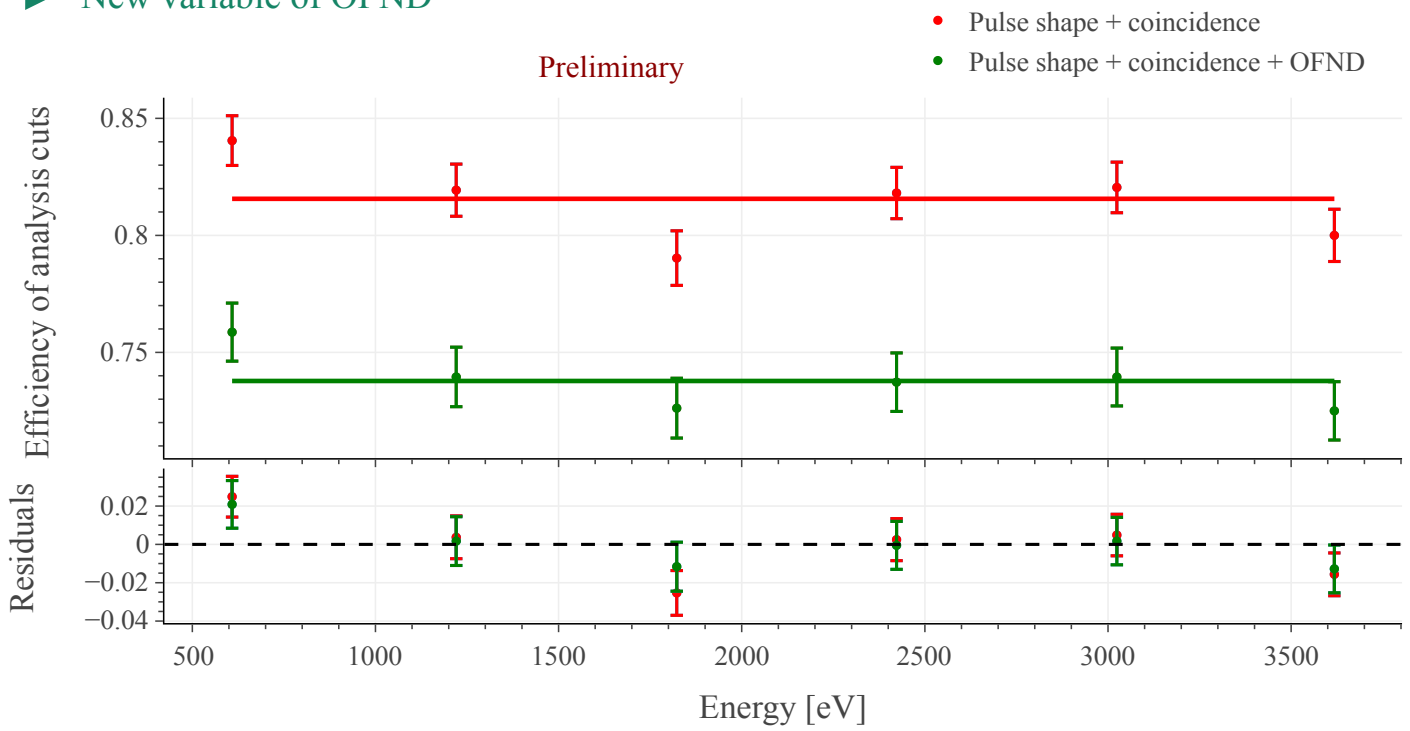


Cuts and efficiencies

Analysis cuts:

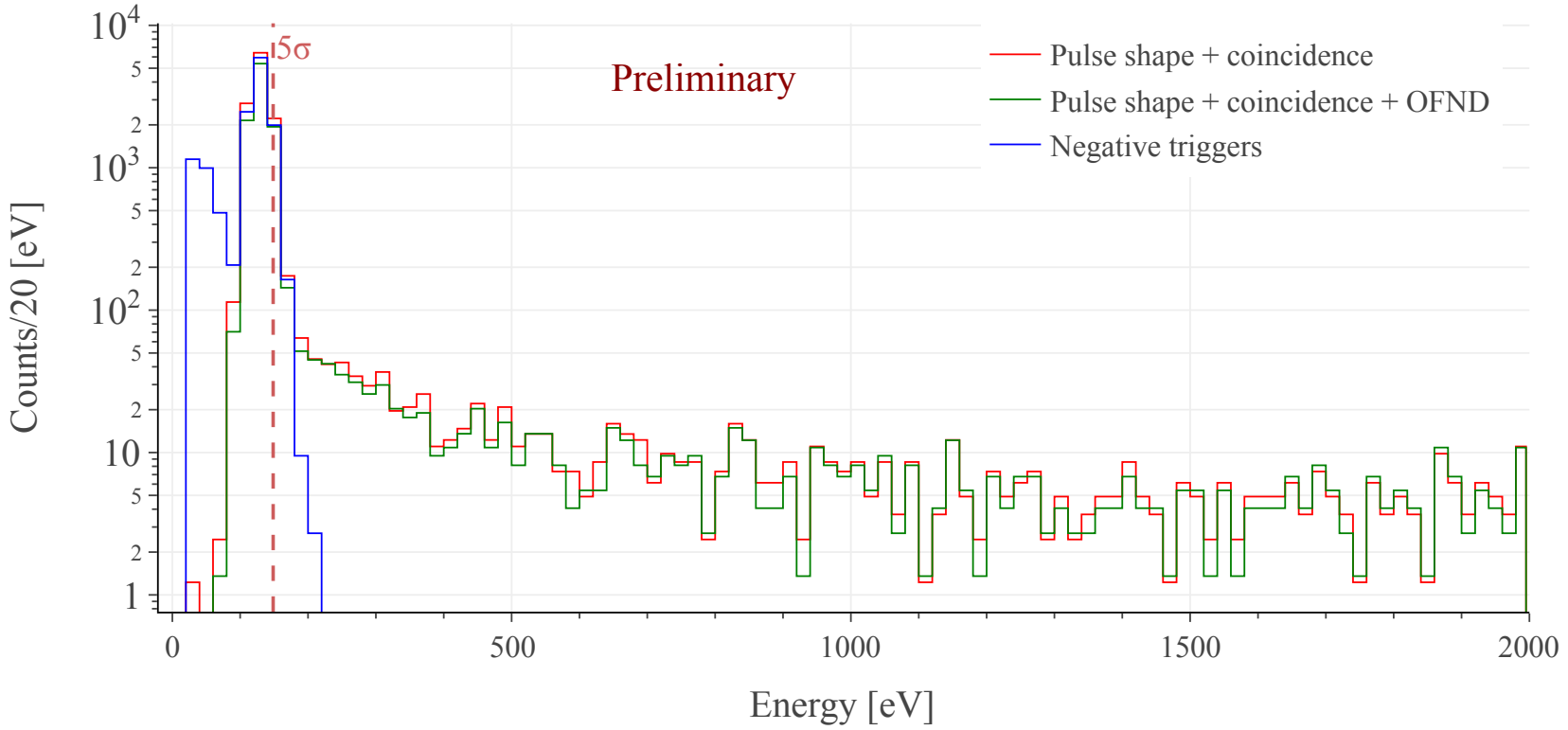
- Basic pulse shape cuts → Pulse shape cuts from basic parameters and optimum filter
- $\chi^2_{OF} < 1.3$
- $\Psi_i < 3$ → Coincidence cuts (see here for the variable definition)
- $\Omega < 5$
- *A-A'* (linearized) < 1.5 → New variable of OFND

Variables built to have a flat efficiency until threshold.
The efficiency is around 70-80 %.



Preliminary energy spectrum

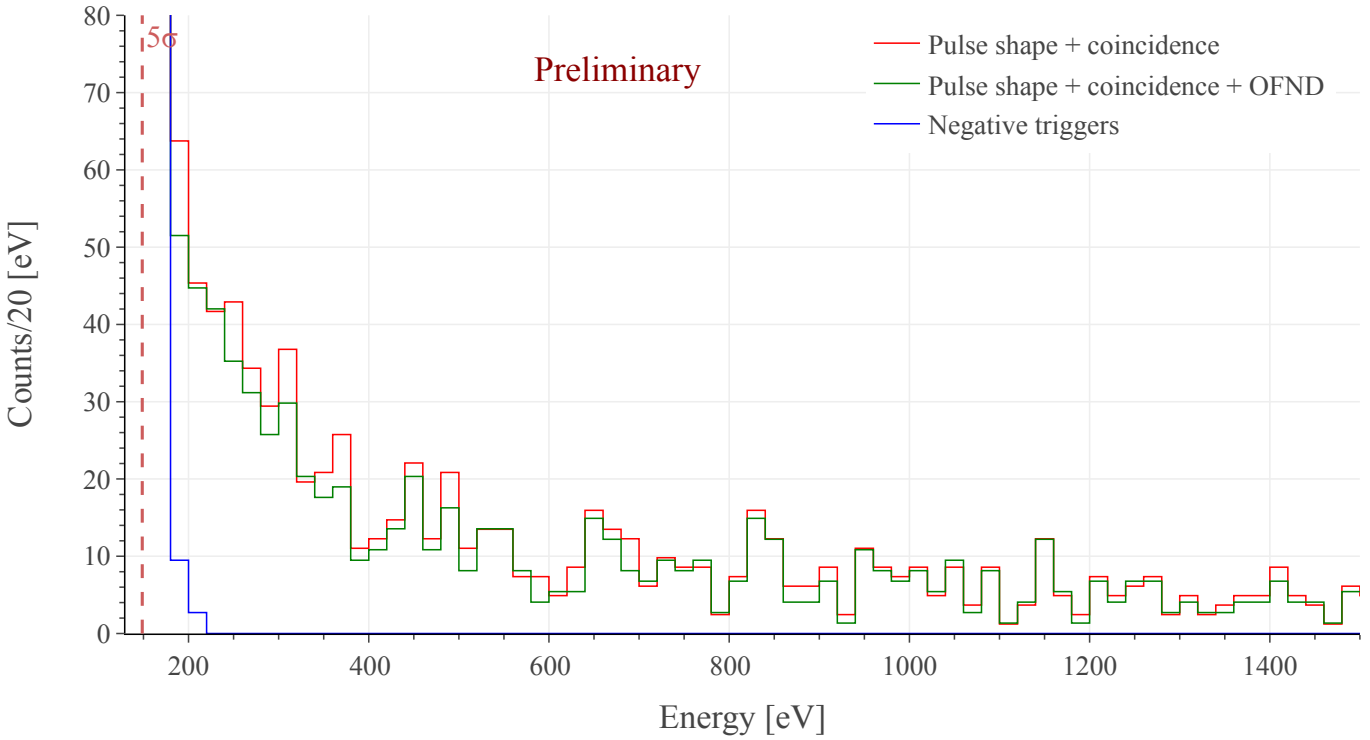
This spectrum is in counts but corrected for the cut efficiencies.



Rise from ~ 600 eV still visible, the overall level is not much changed by the new cut.

Preliminary energy spectrum (linear scale)

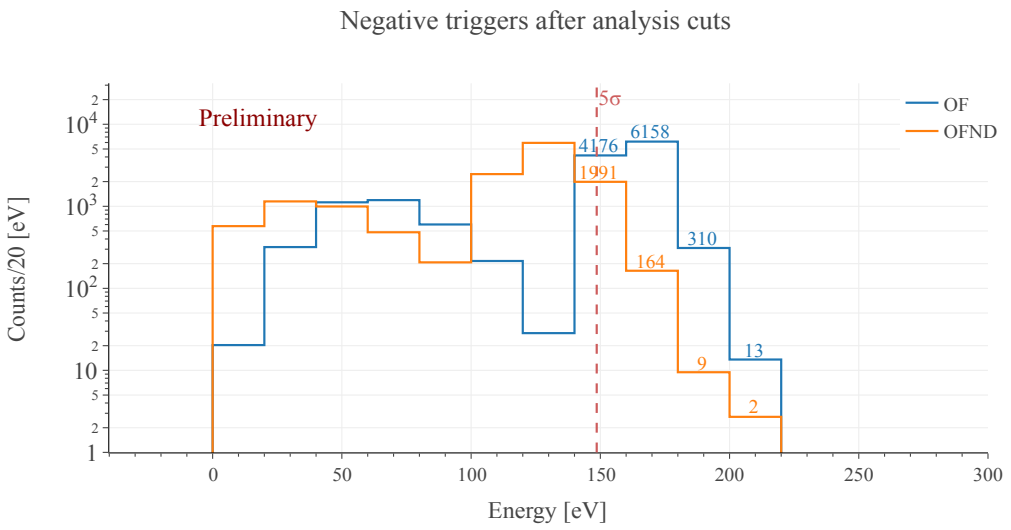
This spectrum is in counts but corrected for the cut efficiencies.

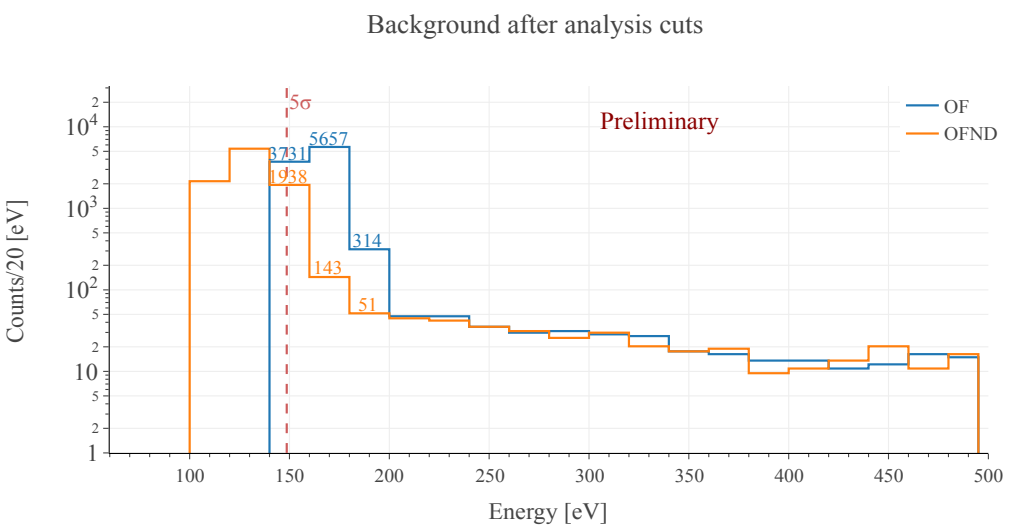


Rise from ~ 600 eV still visible, the overall level is not much changed by the new cut.

Gain with the multidimensional filter

The exponential rise due to the negative triggers begins closer to the energy threshold with the multidimensional matched filter.





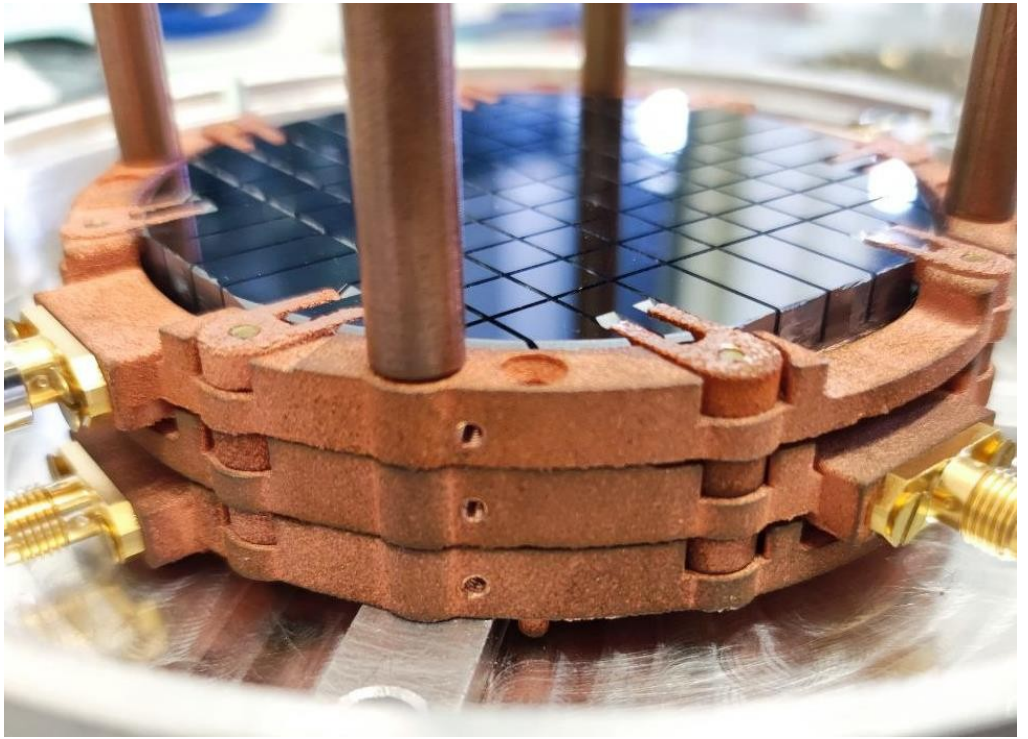
Still, the negative triggers dominate the spectrum at low energies.

Next steps

Preliminary analysis shows an improvement of 10-15 % in the baseline resolution and less negative trigger rate near threshold.

To do:

- Investigate variables to possibly discriminate between negative triggers and signals
- Play with cuts to further reduce the background level
- Continue studying the rise at threshold



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Thanks for your attention!